Project FEELEX: Adding Haptic Surface to Graphics

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Limitations in current haptic interface

Some people cannot feel virtual objects.

Reasons:

(1) Point contact.
haptic surface is not spatially continuous

(2) Separated visual/haptic display

Desktop Force Display
(Iwata, SIGGRAPH 90)

Goals of the Project FEELEX

(1) to provide a spatially continuous surface that enables users to feel virtual objects using any part of the fingers or even the whole palm.

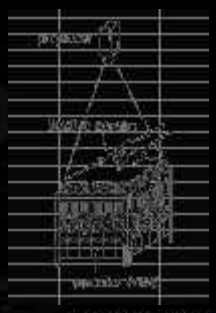
(2) to provide visual and haptic sensations simultaneously using a single device that doesn't oblige the user to wear any extra apparatus.

Basic Idea of FEELEX

(1) Image is projected onto a flexible screen.

(2) Flexible screen is deformed by an actuator array.
→ user can directly touch the image by bare hand

(3) Hardness is presented according with force sensing.



Related Work

(1) Haptic Interface
exoskeleton; Iwata(1990), Burdea(1992)
tool-handling-type; Iwata(1993), Massie(1994)
object-oriented-type; Tachi(1994), Hirota(1996)

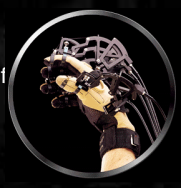
(2) Real World Graphics
Wellner(1991), Ishii(1999)

Method for Haptic Interface (1) exoskeleton

Set of actuators attached to hand/body

Advantage:
many degrees of freedom

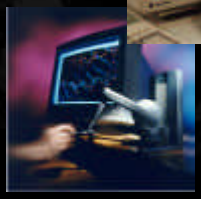
Limitation:
difficulty in putting on/off



Method for Haptic Interface (2) tool-handling-type

Pen-based device

Advantage:
Free from fitting



Limitation:
Single-point contact

Method for Haptic Interface (3) object-oriented-type

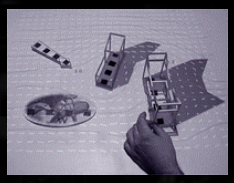
Device deforms to simulate virtual object.

Advantage:
continuous surface contact

Limitation:
difficult to fabricate

Real World Graphics

Image projection on physical objects



Advantage:
intuitive interaction

Limitation:
deformation is not presented

I/O Bulb (Hiroshi Ishii)

FEELEX = object-oriented-type haptic interface
+ real world graphics

Prototype Implementation FEELEX 1

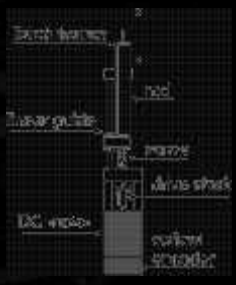
Design specification

Double-hand, whole palms
→ 24cm X 24cm screen

motor with tangible force
→ 6 X 6 actuator array

Actuator for FEELEX 1

1) Screw mechanism
self-lock
→ free from vibration
stroke = 80mm
max speed = 100mm/s



2) Force sensor
strain gauge
→ presents hardness

Graphics for FEELEX 1

Projected grid on the deformed screen

Anomarocaris

Video (FEELEX 1)

Prototype Implementation FEELEX 2

Design specification

- Improved resolution
- Palpation by fingers
- Hard object smaller than 8mm is difficult to palpate (Lederman & Klatzky, 1999)

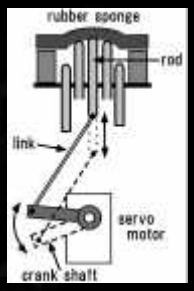
→ rod size = 6mm
distance between rods = 8mm
display area = 5cm X 5cm

Actuator for FEELEX 2

1) Piston-crank mechanism
Servo motor is much larger than 8mm
→ placed at offset position

stroke = 18 mm
max speed = 250 mm/s
max force = 1.1 Kgf

2) Force sensor
measuring electric current



Video (FEELEX 2)

Evaluation of FEELEX 1

Test environment:
SIGGRAPH 98
Content:
Anomarocaris
Procedure:
only a signage saying "You can touch it"
Number of subjects:
1,992

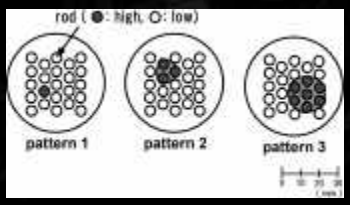
Result of Observation of User's Behavior

Category	number of subjects
(1) Touched the creature using a single finger	299 (15%)
(2) Touched the creature using multiple fingers	319 (16%)
(3) Touched the creature using the whole hand including the palm	1374 (69%)

85% of the subjects used multiple fingers or their palms without instruction.

Evaluation of FEELEX 2
Recognition Performance of Palpation

Task: Invisible hard objects are displayed (3 patters). Subjects are asked to draw position and size of the hard object on a piece of paper.



Evaluation of FEELEX 2

Subjects:

9 university students (7 males, 2 females) ranged in age from 22 to 24.

Procedure:

We prepared three trials for each pattern.

The three patterns are displayed in random order, and thus each subject completed a total of 9 trials.

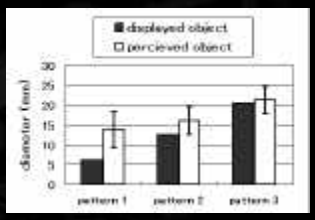
The subjects were asked to draw the object that they perceived for each trial.

Results of Evaluation (1)
Size of Perceived objects

The size of a perceived object is represented by the approximated diameter of the figure drawn by the subjects.

$$d = \sqrt{4S/p}$$

Where
d = approximated diameter
S = measured area

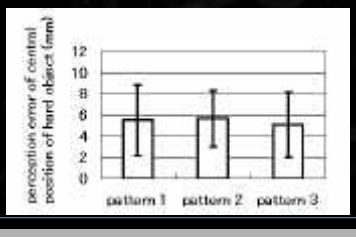


Perception error is smaller than finger tip.

Results of Evaluation (2)
position of Perceived objects

We calculated the center of mass of each perceived object.

→ **Position error is less than 6mm**



General Discussion for the FEELEX

(1) advantages

- natural interaction
  success in long term exhibition in a museum
- safety
  free from vibration or unwanted force

(2) disadvantages

- difficulty in hardware implementation
- limitation of simulated shape
  sharp edge, backside of object

Applications for the FEELEX

- **Palpation simulator**
  training, tele-medicine
- **3D shape modeling**
  virtual clay
- **Touch screen**
  barrier-free solution
- **Art**
  interactive sculpture

Conclusion

Prototype FEELEX provides natural haptic interaction.

Effectiveness is tested through exhibition and palpation experiments.

Future Work

Development of new mechanism

- ability to simulate various shapes
- low-cost, easy to fabricate, mechanically robust